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ABSTRACT

The goal of this research synthesis is to evaluate the validity of the claim that there are fundamental limitations on the ability of adolescents to engage in critical thinking. Critical thinking is defined as an analytic, focused cognitive activity aimed at understanding phenomena at a root rather than a superficial level; a type of thinking closely though not exclusively associated with formal thinking as described by Piaget. This paper examines what fundamental cognitive developmental limitations have been claimed or implied regarding adolescents' abilities to engage in critical thinking, what empirical evidence has been used to support or refute these claims, what empirical evidence exists to demonstrate that adolescents are able to engage in such thinking, and what recurring themes emerge from consideration of all this evidence. Evidence is reviewed within four broad headings: (1) Piaget's formal operations; (2) biopsychological constraints; (3) individual differences; and (4) cognitive processing analyses. It is concluded that there is no persuasive evidence of fundamental constraints on the ability of early adolescents to engage in critical thinking. Sixty-three references are included. (NB)

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EXECUTIVE SUMMARY

ADOLESCENTS' ABILITY TO ENGAGE IN CRITICAL THINKING

There has been considerable concern recently among educators and the public at large regarding the relative absence of critical thinking among adolescents in school, from the middle or junior high school years onward. A number of possible explanations have been advanced to account for this. One explanation which has been influential for educational practice is the claim that there exist fundamental cognitive developmental limitations on the ability of adolescents in general, and early adolescents in particular, to engage in such thinking. If this claim is correct, then the goal of improving educational practices so as to encourage critical thinking in the middle and junior high school years may be misguided. On the other hand, if the claim cannot be shown to be correct, then the development of appropriate and innovative educational programs and practices may be encouraged. The goal of this research synthesis, then, is to evaluate the validity of the claim that there are fundamental limitations on the ability of adolescents to engage in critical thinking.

There are many potential definitions of the key term, critical thinking. It is not a purpose of this review to categorize or reconcile such definitions. The operative understanding for this review is thinking which is described as analytic and focused cognitive activity, whose aim is the understanding of phenomena at a root rather than superficial level. In research and in educational practice, such thinking has been closely though not exclusively associated with formal logical thinking, of the sort described by Piaget. Further, it is with respect to such a construct that the clearest claims have been made regarding fundamental cognitive developmental limitations.

The synthesis is organized around four related questions. 1) What fundamental cognitive developmental limitations have been claimed or implied regarding adolescents' abilities to engage in critical thinking? 2) What empirical evidence has been used to support or refute these claims? 3) Conversely, what empirical evidence exists to demonstrate that adolescents are able to engage in such thinking? 4) What recurring themes emerge from consideration of all this evidence, and in what ways are these themes useful for guiding the development of appropriate educational programs and practices?

The evidence is reviewed within four broad headings: Piaget's formal operations; biopsychological constraints; individual differences; and cognitive processing analyses. The conclusion of this review is straightforward: *There is no persuasive evidence of fundamental constraints on the ability of early adolescents to engage in critical thinking.* Although researchers in these fields have noticed that performance on certain types of thinking tasks seems to increase with age, a variety of evidence suggests that (a) performance is often the result of a person's experience, education and formal training in highly specific content areas; (b) brain growth and physiological maturation have not been isolated to substantiate clear connections to cognitive performance in early adolescence; and (c) neither research on individual differences nor on cognitive processing has established the influence of

general underlying and untrainable capacities on cognitive performance in specific domains. Conversely, highly motivated adolescents and younger children in supportive environments show impressive cognitive performance in specific areas; this suggests great potential for critical thinking. To the extent that the low frequency of such thinking in schools is a concern, then the evidence suggests that the principal source lies in the structure of educational practices.

Several important issues which need to be taken into account in the development of educational programs do arise in the context of reviewing the available research evidence. Key among these are the relative domain-specificity of critical thinking, as opposed to general ability or universal structure models; the conception of critical thinking as both a skill and a disposition or orientation; and the relative interdependence of cognitive activities which support critical thinking, especially the centrality of expertise in relevant domains of knowledge. Innovative educational programs which take advantage of these emerging perspectives of contemporary research may be expected to achieve greater impact.

ADOLESCENTS' ABILITY TO ENGAGE IN CRITICAL THINKING

The core concept of this review, "critical thinking," has traditionally been understood in a variety of ways. Indeed, one might view the concept as obfuscated by the many taxonomies and schemes that have attempted to categorize this diversity. Given the overlap among taxonomies and schemes, it has become increasingly difficult to specify the concept clearly (Nickerson, Perkins, & Smith, 1985).

We can, however, specify several key elements. First, we can draw a distinction between thinking that tends to be analytic, focused, and formal, versus that which is synthetic, global, and informal. Analytic thinking is more often associated with schooling and educational outcomes; indeed, it is an identifiable goal of much academic training. Informal thinking has received the more recent attention of researchers interested in those types of thinking typically less valued within educational contexts, such as creativity or social intelligence (e.g., Gardner, 1983; Wallach, 1985). We can make a secondary distinction between thinking that requires the transformation, application, or interpretation of knowledge versus thinking more typically viewed as "automatic" that involves only the recall of information or rote procedures.

For the purposes of this review, I will identify as "critical thinking" those cognitive activities described by the first pair of each of these dimensions. That is, cognitive activity which is analytic and focused for the purposes of understanding something at a deeper than superficial level, and which requires activities of transforming or interpreting information -- rather than the rote application of procedures -- can fairly be termed "critical thinking." In the existing research on adolescent cognition, this is most clearly identified with the Piagetian notion of formal operational reasoning (Inhelder & Piaget, 1958; Keating, 1980b), although other approaches can also be identified.

Two related observations provide the focus for the question addressed in this review. First, the relative absence of critical thinking from middle, junior, and senior high schools -- and possibly, beyond those levels -- has been a focus of much recent educational concern and discussion (e.g., Fredericksen, 1984; Goodlad, 1983). Second, there is an explicit or implicit belief in some segments of education that early adolescents are not yet capable of sustained critical inquiry, and thus we should abstain from curriculum and instruction which requires it (e.g., Epstein & Toepfer, 1978; Toepfer, 1979).

The key questions of this review, then, can be simply stated: What is the evidence for the claim that fundamental constraints exist on the ability of early adolescents to engage in critical thinking.

The question is of central educational importance. If one believes that certain types or forms of thinking are inaccessible early in adolescence, then it is inappropriate and ill-advised to include and plan curriculum or instructional practices that seek to foster

these types of thinking. On the other hand, if one believes that such thinking is accessible to adolescents, even if not always evident in their current performance, then one might elect to direct educational efforts to develop and enhance such abilities. Indeed, it may be a sensitive period for establishing such skills. This assumes, of course, that one values the development of critical thinking. In practice, there is a clear consensus that critical thinking is desirable as well as dismay that its practice appears so seldom in educational settings.

If we can clearly demonstrate that, because of fundamental developmental limitations of adolescents, such thinking is not possible, then educational efforts to promote it should be reduced or even ended. Therefore, it makes sense to focus initially on the empirical and theoretical literature which claims that such thinking among adolescents is fundamentally impossible. Such claims have been made, more or less explicitly, and have had considerable impact on educational practices in the middle and junior high schools (e.g., Epstein, 1978; Toepfer, 1979). Even in their absence, many educators have assumed that Piaget's theory directly implies that some forms of thinking are inaccessible to the early adolescent, and thus doubt that attempts to elicit critical thinking until much further into adolescence will be effective.

Perhaps a concrete example can illustrate this more clearly. In research with mathematically precocious youth, we found a number of students at age 10 or 11 years who performed on standardized mathematics aptitude and achievement tests similarly to college-bound high school seniors (Keating, 1976). It was common for educators, who accepted the implicit belief in fundamental developmental constraints, to argue that such students should not be exposed to advanced mathematics, because they still lacked the formal reasoning structures. In practice, however, such students performed in ways that were indistinguishable from those older adolescents, both on formal reasoning tasks (Keating, 1975) and in university classrooms (Keating, 1976).

THE QUESTIONS

I will discuss the thinking activities that are, as mentioned above, more formal and analytic, and which also involve the transformation, application, or interpretation of knowledge. Therefore, this research synthesis focuses on empirical evidence about adolescents' capabilities to engage in such thinking, which I will term "critical thinking." Four major questions serve to frame the review:

1) What fundamental developmental constraints are stated or implied in the research literature about adolescents' capabilities in these areas?

2) What empirical evidence can be used to support or refute such claims?

3) Conversely, what empirical evidence exists to demonstrate such capabilities are present in early adolescents?

4) What recurring themes emerge from this review of the literature that indicate how critical thinking may be developed and how may these themes be useful to guide our own thinking about educational practices?

With these questions in mind, we can turn our attention to the several research perspectives that are relevant to whether fundamental developmental constraints on thinking exist in adolescents. In separate sections of this synthesis, I will review research from a Piagetian, a biopsychological, an individual differences, and a cognitive processing perspective. Following my empirical reviews, in a concluding section I will briefly discuss several emerging themes and their implications for educational practice. One further caveat is that researchers cited here may or may not adhere to the belief in fundamental constraints.

PIAGET'S FORMAL OPERATIONS

One of the most specific proposed constraints on adolescents' exercise of higher order thinking is the claim that many of them lack the logical structures to engage in formal thinking. Although this position may show that Piaget's claims are misunderstood or only partially understood (Byrnes, in press; Inhelder & Piaget, 1958; Keating, 1980b, in press a,b; Piaget, 1972), it is clearly an influential one in educational practice. Some advocates of this view have proposed that cognitive instruction be suspended entirely or else sharply limited; they argue that until the structural changes which permit formal thinking in adolescents have had time to develop, instruction that requires critical thinking is basically futile.

The fundamental tenets of this belief system are widely known and can be briefly summarized (see Gelman & Baillargeon, 1983; Inhelder & Piaget, 1958; Keating, 1980b; Piaget, 1972). First, as the central story in cognitive development, Piaget focused on logical operations and their organization. Second, the emergence and development of these operations proceeds through four major stages: Infant sensorimotor development; preoperational thinking in early childhood; the concrete operations of the school-aged child; and the formal operations of adolescence and adulthood. Third, the operations and schemes within any given stage are integrated into larger structures, and thus stage changes imply broad shifts in the underlying structure. Finally, this progression is presumed to be universal and invariant.

Piaget's perspective is unparalleled for its seminal influence on research in cognitive development. Much of this work initially involved replication and, occasionally, extension of the tasks generated by Piaget and his Genevan colleagues to illustrate how these developing logical structures function. The principal tasks for research on formal operations, believed to emerge during adolescence, were those drawn from Inhelder and Piaget (1958). Early evidence tended rather convincingly to affirm the sequence and approximate age-equivalence of performance on these tasks as initially reported by Piaget and his colleagues.

Subsequent research, beginning in the mid-1970s, began to raise significant doubts about the key theoretical claims. More recent critical reviews of the evidence from the entire age range have tended to coalesce these doubts into an emerging consensus (Carey, 1986; Gelman & Baillargeon, 1983; Keating, 1980b). "In our opinion there is little evidence to support the idea of major stages in cognitive development of the type described by Piaget" (Gelman & Baillargeon, 1983, p. 214). Or even more starkly, "Piaget's stage theory has come under fire and has been abandoned by many developmental psychologists. It is probably fundamentally misleading. [M]any developmental psychologists now believe that the young child does not think differently from the adult, is not concrete, illogical, and so forth" (Carey, 1986, p. 1129).

Although this reconceptualization may not be universal among developmentalists (see, e.g., Byrnes, in press; Byrnes & Overton, 1986), it has clearly emerged as the currently dominant view. What is the nature of the evidence that has led the field in this direction? In the research reviewed below, the focus is on evidence from the preadolescent and adolescent period, although similar issues emerge in earlier developmental periods as well.

The evidence in favor of a pervasive structural shift in logical capacity rests on interpreting the inter- and intra-individual variation in children's, adolescents', and adults' performance on a number of different tasks. In order that this evidence supports the major theoretical claims, these task performances should demonstrate three important characteristics.

1) It is necessary to show that the performance variance can be unambiguously attributed to differences in logical capacity, as opposed to some other aspects of performance, such as memory, attention, encoding and so on, and as indicative of propositional logic specifically.

For several decades a controversy has existed about whether the performance patterns on a variety of formal reasoning tasks can be attributed to an adolescent (or later) shift to a specifically propositional logic. Braine and Rumain (1983) and Keating (1980b) summarize much of this work. It would appear from these analyses both that the performance patterns do not require the use of Piaget's full propositional system (Bynum, Thomas, & Weitz, 1972), and that other logical systems can potentially account for the same evidence (Osherson, 1975). Also, there is increasing evidence that a formal propositional logic is quite rarely invoked, even among adults (Kuhn, Amsel, & O'Loughlin, 1988; Cheng, Holyoak, Nisbett, & Oliver, 1986). Instead, some rather looser array of pragmatic reasoning schemas tend to be the method most adults and adolescents use when confronting logical problems, a point to which I return below.

It is on the related issue -- unambiguous attribution of performance differences to changes in logical functioning -- that the greatest amount of empirical data has been accumulated. An early and influential study focusing on this issue is Bryant and Trabasso's

(1971) study of preadolescents, which led to an extended research program on the problem of transitive inference later summarized by Trabasso (1975). Transitive inference refers to the ability to draw conclusions about the relationship between two terms that have not been directly compared, but that have each been compared to a separate term. For example, if A B, and B C, which is greater, A or C? Depending somewhat on the nature of the task materials and the number of terms to be compared, the typical finding in Piagetian research had been that full understanding of transitive inference occurs late in the concrete operational period, and indexes the beginning of transition to the next stage of formal operations.

The evidence over a number of studies (Trabasso, 1975) can easily be summarized. On the standard transitive inference tasks, young children generally have near-zero level performance. After being shown a series of premises -- in these cases, involving sticks of varying lengths -- the child is asked to make the transitive inference. With five sticks, then, the child is shown four pairwise comparisons: A B, B C, C D, D E; and then is asked, "Which is longer, B or D?" (The use of B and D is to avoid "end-anchor effects" -- each stick, B and D, is included as both longer and shorter in one comparison). In this standard procedure, young children routinely fail this question.

However, if one asks these children, "Which is longer, B or C?" -- recall that they have been shown this comparison directly -- their performance is equally poor. In other words, they fail to recall the premises. Their failure on the inference question cannot therefore be unambiguously attributed to a logic failure; without accurate recall of the premises, failure on the inference question cannot be meaningfully interpreted. Proceeding from this evidence, a training procedure was introduced to ensure accurate recall of the premises by the children. After clear evidence of ability to recall the premises on several trials, the children were again asked the transitive inference question. In these cases, children as young as four to five years were able to answer correctly on a large majority of trials (over 80%). Counterarguments focused on the ways in which the task might change as a result of studying the premises, and on the selective nature of the young children who could master the memory demands. But the point remains largely the same: The performance failure in the standard task cannot be attributed clearly to differences in logical competence.

Following this prototypical series of studies, many similar studies have been done using other tasks (see reviews by Gelman & Baillargeon, 1983; Keating, 1980b, in press b). The overall impact of such research is quite clear. On many of the tasks which have been used as indices of emerging logical competence, the effect of altering non-logical features of the task is substantial, sometimes dramatically so. Generally, results have indicated that logically equivalent versions of the standard tasks can be successfully solved by much younger children. (However, these standard tasks have been adapted to reduce memory load, to enhance the salience of key task characteristics, to clarify the nature of the question being asked, to use more familiar content, or to make other adjustments which do not alter the logical demands of the task.) It is also possible, however, to show that the

effects of such non-logical features may increase the difficulty of some standard tasks. Crane and Keating (1986), for example, showed that a substantial percentage (45%) of college students with a good working knowledge of fractions and ratios were nonetheless unable to effectively apply that knowledge to a concrete proportional comparison.

The general conclusion from evidence on this point is thus clear. Even though any number of tasks may have specifiable logical requirements -- although alternative logics may exist which might do as good a job in some instances -- it is not safe to assume that success or failure on the task can be equated with presence or absence of the logical structure. Certainly, conclusions based on task failures that a particular form of thinking is impossible for a particular child or within a particular age range, are completely unwarranted, and have routinely been shown to be false on close investigation.

2) **It is necessary to show that the change in performance occurs systematically within and across individuals.**

The focus of this claim is that changes in underlying structures are arranged in stages. Such a stage view implies that the changes in performance that are associated with changes in structure should emerge in a clearly coordinated fashion. The primary evidence for this claim lies in the discovery of clear sequences of task or skill acquisition, and in the pattern of covariation (or correlation) between tasks drawn from different content domains. That is, if the change is structural, its effects should be pervasive across a variety of tasks within a relatively short time and in some reasonably replicable sequence.

As might be expected based on the findings of wide variability in performance depending on the content and context of the task, reliable sequences between tasks have proved difficult to demonstrate, both at the concrete and formal operational levels (Gelman & Baillargeon, 1983; Keating, 1980b; Siegler, 1981). Two particular features of research which has sought to establish such sequences are noteworthy. First, although some orderings of tasks in specific studies have shown reasonable reliability across persons when ordered from least to most difficult, the particular scales are easily disturbed by minor modifications of the tasks. Second, in many studies the issue of measurement error has not been adequately addressed. For example, the number of subjects who "conform" to the grouped-average order has frequently been compared to the number who are "out of sequence." This proportion is significantly favorable for the theory in some studies. But when we include those subjects for whom assignment as "conformers" or "non-conformers" can not be made (that is, the "uncertain" category), the proportion of "conformers" drops substantially, often to well less than half the sample (Keating, 1980b).

Also, if change is stage-like, we would expect to see somewhat abrupt rather than continuously gradual changes in performance, possibly at the level of grouped data, and necessarily at the level of individual data. There are relatively few longitudinal studies of acquisition of formal reasoning, and there are methodological difficulties with those which do exist (Keating, 1980b). Training studies provide a different sort of opportunity to

observe the change process, though necessarily a "non-natural" change. Kuhn, Ho, and Adams (1979) reported a training study with pre- and late-adolescents. Although they found progress toward more formal reasoning in both groups, and a somewhat stronger and broader effect in the older students, it is clear that progress was generally fitful and unstable. In a somewhat more detailed case study including both experimental and control subjects from the fifth and sixth grades, Kuhn, Amsel & O'Loughlin (1988) provide a more detailed look at a number of the specific strategies involved in acquiring the ability to coordinate theory and evidence. At this microgenetic level, it is even clearer that progress, even in individual case studies, shows numerous fits and starts (Kuhn et al., Tables 28 and 29, pp. 202-203).

Understanding the educational implications of these and similar findings is crucial. If, at some point in development, it is impossible to engage systematically in formal thinking, and if at some later point a developmental shift enables formal thinking processes, then that type of developmental reorganization should be apparent in some type of discontinuity in longitudinal, training, or grouped cross-sectional data (listed in order of how convincing the evidence would be). For example, in a recent cross-sectional study examining the development of deductive reasoning across a variety of levels of content familiarity and contextual support, Overton, Ward, Noveck, Black, and O'Brien (1987) report the percentages of subjects from fourth through twelfth grades (at two-year intervals) who perform in a logically consistent manner on a series of syllogism tasks. Although there are varying patterns of significant effects between groups which lead Overton et al. (1987) to identify the sixth- to eighth-grade period as central to the formal reasoning transition, their overall data from the three experiments reveals a gradual, linear, and monotonic growth across the whole age range (Overton et al., 1987, Figure 1, p. 25). Reviewing this and similar data (Keating, 1980b), an objective observer is unlikely to infer abrupt or discontinuous transitions, even in grouped, cross-sectional studies.

Note that the absence of this type of fundamental developmental reorganization does not rule out the possibility that, in the acquisition of skill or knowledge in particular domains, individuals might show definable qualitative shifts in performance. Indeed, such transformations are a key part of Vygotsky's (1978) notion of qualitative, dialectical progress in skill acquisition. But the argument for withholding some kinds of educational experiences until some fundamental developmental transition occurs does make a stronger claim. The qualitative shifts during skill acquisition proposed by Vygotsky (1978) may occur at any point in ontogenesis. The traditional Piagetian claim is that some acquisitions are not possible until a specific structural transition has occurred. This latter claim requires rigorous evidence of such a fundamental transition point; evidence of this calibre has not yet been forthcoming. (Note 1)

3) **It is necessary to show that the emergence of such reasoning occurs universally, both across content areas and across persons.**

One of the most frequently reported findings in the research literature on formal operations is that the success rate among adults on the standard Inhelder and Piaget (1958) tasks is far from 100%. Indeed, the more typical finding is success in the 40% to 60% range, depending on the tasks used and other factors (Keating, 1980b). To account for the repeated failure of adults to perform competently on the original formal reasoning tasks, Piaget (1972) proposed the following explanation. He acknowledged that adults may well vary in their familiarity with the content of these tasks, which were largely drawn from the mathematics and physical sciences. Thus, lack of knowledge about the content domain of the task might well interfere with adults' (presumed) abilities as formal reasoners.

But this invocation of content knowledge -- though probably correct in a larger sense -- does not resolve the internal contradictions in the claims regarding a structural shift in logic. If the inadequate performance of the adults is explained by weak content knowledge, then the same inadequate performance by children and adolescents cannot sensibly be attributed to a different cause, namely, the absence of certain logical structures. Some empirical studies (e.g., Keating & Clark, 1980) have, in fact, yielded little evidence that the use of more familiar content knowledge -- interpersonal relationships, for example -- significantly enhances adolescents' logical performance. Using Selman's (1980) model of interpersonal reasoning, Keating & Clark (1980) employed a multi-trait, multi-method design to examine the construct validity of interpersonal reasoning and to examine levels of performance in a different domain. The inclusion of the presumably more familiar domain resulted in very little change in the standard findings. On the typical Piagetian tasks, about 60% of the twelfth-graders showed the advanced levels of reasoning. Adding those students who failed the Piagetian tasks but showed advanced reasoning on the interpersonal tasks increased the success rate only slightly, to about 70%. Using the most stringent criterion, success in both domains, brought the success rate down to the lower of the typically reported levels, about 40%.

There are now a large number of studies examining adults' reasoning in a variety of everyday tasks, as opposed to formal syllogisms or the traditional Piagetian tasks (see Kuhn et al., 1988, Chapter 2 for a brief review). In these studies as well, the findings are quite consistent: If we use reasonable criteria for defining the application of formal reasoning rules, or advanced levels of informal reasoning, the success rate for adults remains surprisingly low.

The point here is straightforward. If one infers from adolescents' generally weak performance on both formal and informal reasoning tasks that they lack a fundamental ability to engage in such reasoning, then one cannot avoid making the same inference from similar performance patterns among adults. The rules for inferring competence from performance must logically be the same, irrespective of the category of subject (as child, adolescent or adult). In the early research literature, adolescents' failures were routinely interpreted, in accord with the theory, as the absence of competence. That inference formed the basis of many educators' views regarding what was and was not appropriate for

the curriculum of the middle school and junior high school. Further research has shown that inference to be empirically unfounded.

To concretize this point, it is interesting to note that in the Overton et al. (1987) data, the proportion of fourth-graders who perform in a logically consistent manner is about the same as the percentage of twelfth-graders who fail to do so (about 20%; Figure 1, p. 25). Similarly, in a series of studies on the ability of subjects to coordinate theory and evidence, Kuhn et al. (1988) report a steady progression of success from third grade through college, with a somewhat larger change between sixth and ninth grades -- though not dramatically larger. But a sample of non-college adults performed at a level intermediate between the sixth and ninth graders.

It would thus be inappropriate to conclude, on the basis of increasingly convergent evidence, that critical thinking is generally inaccessible to adolescents. Even more clearly, there is no convincing evidence that adolescents' failure to display such thinking can be explained by the absence of certain logical structures. A pattern of gradually increasing skill in formal and informal reasoning, dramatically influenced by experience, content familiarity, education, and contextual factors, is a fair account of the existing evidence. The particular role of educational level is evident in a number of studies (such as Kuhn et al., 1988). At the conclusion of a review of the development of logical reasoning, Braine and Rumain (1983) note that "[a]t the high school level, we suspect that both analytic comprehension and reasoning strategies would turn out to be readily teachable and to have broad beneficial effects in improving argumentation and reasoning as well as in helping students write so that ideas are put into words from which the ideas can be recovered (pp. 326-327)." On the basis of the available evidence across a wide variety of studies, there is little reason to doubt that suspicion. Developing the supportive educational environment does, of course, offer a substantial challenge for educators, given the reported absence of such skills from the repertoires of many adults.

BIOPSYCHOLOGICAL CONSTRAINTS

Although the majority of empirical work central to claims that there are fundamental developmental constraints on adolescents' cognitive activity occurs within the context of research on formal operations, there are claims that there are also constraints based explicitly on physiological grounds. The first of these claims focuses on possible "brain growth spurts" at about the time of puberty, and hypothesizes that certain cognitive functions are closely tied to such spurts (Epstein, 1974). The second is less explicitly neurological in terms of hypothesized mechanisms, but instead focuses on the timing of puberty as an enabling or inhibiting factor for developing advanced levels of certain kinds of abilities, especially spatial abilities (Waber, 1976, 1977).

The most explicit argument for fundamental physiological constraints on adolescent higher order thinking is that based on the neurophysiological work of Epstein (1974). His

argument, which linked changes in cognitive functioning as indexed by Piagetian stage assessments to spurts in whole brain growth ("phrenoblysis"), has been quite influential in the design of curriculum for early adolescents. Its principal influence has limited attempts to introduce "novel" forms of thinking during this age range (Epstein, 1978; Epstein & Toepfer, 1978; Toepfer, 1979). The impact that this work has had on educational and curricular planning for the pre- and early adolescent is regrettable, given that the conclusions were certainly premature, and nearly as certainly wrong. The major problems can be summarized in four categories: empirical; methodological; theoretical; and inferential.

1) The empirical critique has been summarized by Greenough, Black, and Wallace (1987). One key claim of the Epstein (1974) model is that whole brain growth occurs in spurts, and thus it makes sense to look for similarly global transformations in behavior and cognition. Greenough, Black and Wallace (1987) note that "while discrete brain regions definitely progress through something like 'spurts,' in terms of such processes as the generation of nerve cells and of connections between them, different brain regions do so out of synchrony and in a reliable developmental sequence (p. 552)." One could propose that spurts in specific regions might have similar cognitive effects during early adolescence as that proposed for phrenoblysis, but such claims would be even harder to establish empirically, given the intensive integration of neural activity during that period of brain growth. In addition, evidence to support claims that periodicity of whole brain growth also characterizes other species has not been replicated by other investigators (Hahn, Walters, Lavooy, & DeLuca, 1983). Finally, other investigators have not replicated findings of covariation between head-circumference and mental-performance changes (McCall, Meyers, Hartman, & Roche, 1983).

2) Marsh (1985) carried out a methodological critique of Epstein's (1974) findings by reexamining the originally reported data. The conclusion of his analysis was that the claims of related periodicity in whole brain growth and cognitive activity could not be sustained in the original data.

3) The theoretical issue draws directly from Marsh's (1985) critique described in the section above. A key claim is that there is a close relationship between a brain growth spurt in early adolescence and the simultaneous acquisition of the type of reasoning characterized by Piaget as formal operations. As Marsh's work indicated, to maintain that there is an identifiable and fundamental developmental shift in the nature of thinking during that period cannot be empirically supported. In other words, the "target" of causal explanation -- fundamental cognitive restructuring at about the beginning of adolescence -- cannot be said to exist in a meaningful way. Even if a whole brain growth spurt at that time could be empirically established -- which points 1 and 2 suggest is highly unlikely -- it could not easily be linked to a cognitive restructuring that itself has not been empirically established.

4) Finally, even if these empirical problems were to be solved, and both phrenoblysis and a stage-like cognitive change at the adolescent transition were to be established and linked correlationally, the educational inference would still be unwarranted. Establishing a linkage would not necessarily imply that the physiological shift is either causal or necessary for cognitive growth. Qualitatively different evidence than covariation would be required. Since, however, neither of the key elements is empirically established, and hence neither is covariation, the further issue of causal connections is of course moot. As Greenough et al. (1987) note, "Certainly any recommendations that educational practices be modified to accommodate such bursts ... are not appropriate...(p. 552)."

A second, and far more modest, hypothesis linking physiological shifts to adolescent cognitive activity is the proposal by Waber (1976, 1977) that differential maturation rates, specifically linked to brain lateralization, might be implicated in the different levels of spatial aptitude observed between boys and girls. In a recent meta-analysis of the numerous studies generated by this hypothesis, Linn and Petersen (1985) concluded that there is no convincing empirical support for the original hypothesis: "[M]eta-analysis showed no change in the magnitude of spatial ability sex differences in early adolescence; [thus] a pubertal mechanism would seem unlikely" (p. 1493). Some slight overall maturation effects may yet be established, in favor of higher achievement among earlier maturers (Petersen, 1988, p. 600), but whether these effects, if robust, are to be explained in terms of cognitive factors, social factors, or otherwise, is not yet clear (Petersen, 1988). In any case, there is no firm evidence from any extant physiological research to support a claim that there are fundamental developmental limitations on the cognitive functioning of pre- or early adolescents. Indeed, a critical review of the evidence from both the cognitive research on the development of reasoning and the physiological work suggests just the opposite: Namely, that advanced levels of reasoning are well within the reach of these students with appropriate educational supports.

INDIVIDUAL DIFFERENCES

To further support the arguments against fundamental developmental constraints on logical thinking, consider several exceptions to the pattern of relatively weak performance by early adolescents. There is good evidence that some adolescents (and pre-adolescents) are capable of quite remarkable levels of formal reasoning. Such precocity can be rather striking among mathematically talented youth, whether the assessment is of mathematical reasoning per se (Keating, 1974, 1976) or of performance on formal operational reasoning tasks (Keating, 1975). Other evidence comes from the performance of adolescents in domains which require quite advanced thinking, and in which they have become expert -- chess or music, for example (Feldman, 1986).

There is no doubt a temptation to dismiss these examples as special pleading for the "hidden" abilities of adolescents, with the justification that they are, after all, "special" cases -- mathematically talented youth, prodigies, and so on. But such a dismissal would seem

to endorse a particular theoretical perspective: That these youths are in some way inherently different from the broad population whose demonstrated lack of critical thinking causes such consternation. A more useful initial perspective would seek to understand more systematically what was different about the cognitive socialization experiences of such individuals (Keating & MacLean, 1988). Not only might this help us understand what generates the special qualities that we do occasionally observe, but it could also help to identify those features of educational practice which either inhibit or enhance them.

More concretely, the claim might be advanced that higher order or critical thinking may be possible for extremely intelligent pre- or early adolescents, but that most individuals do not have sufficient levels of general intelligence. Although such an argument has some apparently intuitive appeal, it should be judged with caution. First, in the relatively few studies of the effects of training individuals with reasoning skills, general intellectual ability has not emerged as a strong factor in predicting ability to benefit from training (see Kuhn et al., 1988; Nickerson et al., 1985). It should be noted that relatively few careful evaluations of this sort have been done, but at the same time it is clear that educational level does seem to emerge as being closely associated with the ability to profit from training. It may well be the case that children and adolescents with high levels of assessed intelligence may profit more from education aimed at higher levels of reasoning; but it also seems likely that nearly all students would profit substantially.

A second related concern is to raise the level of critical understanding of the notion of "general intelligence." The presumption that high levels of assessed intellectual ability necessarily implies differences on some well-defined underlying trait is not beyond criticism. The well-known goal of psychometric analyses is to define, as objectively as possible on the basis of test/task performance, the structure of human mental abilities. Through factor analysis and related techniques, it is hoped that such structures can be validated. This has proved to be a difficult, and perhaps impossible achievement, due to the unavoidable arbitrariness and ambiguity of factor structures (Keating, 1984; Keating & MacLean, 1988; Sternberg, 1977).

In addition, the attempted operationalization of some of the key features central to critical thinking has led to questionable developmental claims. One notable example is the construct of Gf or "fluid intelligence" (Horn, 1980; Horn & Cattell, 1982). Described in ways similar to several aspects of critical thinking -- abstracting, generalizing, comparing, and applying to novel content -- Gf is most clearly identified with relatively "content-free" tests such as Raven's matrices. This perspective supports the belief that there is a generalizable thinking abilit most evident in the solution of novel problems. The influence of a perspective which emphasizes the presumed "culture-free" notion of intelligence is in the choice of training and testing materials for many programs which presume to assess and then train thinking skills. If the notion is itself flawed, then the hope that training individuals how to solve such tasks will generalize to more substantive arenas of thinking may be similarly misguided. As well, it would raise questions about withholding educational

interventions requiring such abilities, or restricting them to a small subgroup of "advanced" pre-adolescents and early adolescents.

A different perspective on these "content-free" thinking tasks, equally consistent with the evidence (Keating & MacLean, 1988), is that such performance represents a specific, school-acquired skill, rather than a general ability central to a notion of fluid intelligence. As noted, the distinction in neither arcane nor trivial. Many programs of direct instruction for the enhancement of thinking (see reviews by Bransford, Arbitman-Smith, Stein, & Vye, 1985; Chance, 1986; Nickerson et al., 1985) use tasks like these either for training, as criteria of enhanced thinking, or both. If "general intelligence" or "fluid intelligence," as defined and assessed psychometrically, cannot be convincingly shown as central to critical thinking, then the organization of educational programs around those conceptions may be misguided. As noted, existing evidence does not meet these validity criteria (Keating, 1984; Keating & MacLean, 1988).

COGNITIVE PROCESSING ANALYSES

In light of some of the difficulties encountered in research emanating from the Piagetian and psychometric perspectives, many cognitive developmental researchers have moved toward some version of cognitive processing analyses. From this perspective, the roles of many potentially important features of cognitive activity can and have been analyzed. There are at least as many conceptions of human information processing as there are psychometric theories of the organization of human abilities -- in other words, quite a few. Many of these conceptions have focused attention on one or another specific aspect of the processing system, but attempts to describe the system as a whole are relatively rarer. This is unfortunate for our purposes here, because it seems likely that critical thinking is likely to engage many aspects of human cognitive activity.

There are at least two reasons one might wish to organize the information processing system, however conceived, into a number of components. First, one might wish to validate in some way the reality of each of the components. In order to do so, it would be necessary to isolate the operation of one component by controlling or equalizing the function of all other hypothesized components. Second, and more modestly, one might wish to generate a plausible list of possible contributors to performance on some complex cognitive activity. The former goal -- validation of the independent existence of various processing components -- has been elusive (see critical reviews by Keating, 1984; Keating & MacLean, 1987). Rather than review those attempts, I present here a brief description of one plausible division, focusing on an examination of its implications for educational enhancement of critical thinking.

Roughly speaking, a three-fold division of the processing system can be posited: basic operational capacity; a knowledge base, which includes both procedures and semantic information; and an executive monitor of some sort. In the overworked computer analogy,

the first element is most like "hardware"; the second elements are the software and the database, respectively; and the third element is most like the programmer.

With respect to the development of critical thinking and how accessible it is to pre- and early adolescents, the most straightforward case can be made for basic operational capacity. Though considerable controversy remains concerning whether there are fundamental changes in this feature of the cognitive system, there is an emerging consensus that there are few important changes after early adolescence. It thus seems unlikely that the capacity to execute elementary information processes in sufficient quantity or at sufficient speed can be used to explain less than desirable levels of critical thinking in this age group (Keating & MacLean, 1987).

Both kinds of knowledge (content and procedural), however, are deeply implicated in the reportedly low levels of critical thinking among adolescents. Indeed, the transformation of knowledge has begun to emerge as a key focus for research on a range of related topics, from science and scientific reasoning (Carey, 1986; Kuhn et al., 1988) to expertise in a variety of domains (Glaser, 1984; Chi, Glaser & Rees, 1982). Both Carey (1986) and Glaser (1984) argue strongly that expert performance has typically been shown to be highly domain-specific. Glaser (1984) articulates as a first pedagogical principle that "one must understand an individual's current state of knowledge in a domain related to the subject matter to be learned (p. 101)." Educational programs which are aimed at the generation of general problem solving or thinking heuristics -- and "most of these programs (p. 96)" are oriented in this direction -- demonstrate "an avoidance of the complexity of subject-matter information (p. 96)."

The basic issue is whether critical thinking is a generalized and transferable skill, or whether it is intimately bound up in the particulars of a specific content domain. Glaser (1984) contends that the latter is true, and further that the former perspective is based on an early and ultimately less useful model of human cognitive activity. Kuhn et al. (1988), while recognizing the strong evidence for domain-specificity, argue that mastery in some topic areas may lead to a subsequent ability to think critically in related areas. In fact, they argue that one of the crucial achievements lies in the ability to "bracket" one's content knowledge (or intuitive theories) while evaluating evidence -- a procedural type of knowledge -- that may be contrary to that content knowledge. Note, however, that progress in this sense requires movement in both theory and in the evaluation of evidence, and that this does tend to proceed, at least initially, on a domain-by-domain basis. The necessity of integrating these different sources of knowledge (cf. Keating, 1980a) seems to emerge more clearly in the current research paradigms.

Interestingly, nearly all the programs for direct educational intervention on thinking skills are appropriately categorized as attempting to enhance procedural knowledge (see reviews by Bransford et al., 1985; Campione & Armbruster, 1985; Chance, 1986; Nickerson et al., 1985). The typical hope is that if problem solving heuristics or habits of mind are developed with a particular type of material -- usually not tied to any particular subject

matter content -- then students will be enabled to employ these skills in a wide range of specific content domains. If such transfer were to be convincingly demonstrated, it would make a strong counter-argument to Glaser's (1984) specificity position.

In reality, convincing evidence of this sort has not been forthcoming. In many cases, there is little formal evaluation of any sort. Where careful evaluations have been done, the criteria of success are typically the students' performance on materials exactly the same as, or very much like, the training materials. Though this may be a necessary first step in the evaluation process, it is weak evidence of a strong claim (the general enhancement of thinking). The next and crucial step of transfer to quite different kinds of content has apparently not been undertaken in any systematic way. Of course, the criteria may be hard to specify, but without this information the issue is reduced to how effectively particular programs "teach to their own tests."

This is a serious concern, if the early research on expert knowledge systems is borne out. That is, if content knowledge and procedural knowledge are inevitably intertwined, then programs of direct instruction in "general" thinking may be misguided at a rather basic level. The pattern in these training programs is often reminiscent of the creative thinking programs popular not so long ago. In those as well, the target criterion became enhanced test performance rather than genuine creativity, and the focus became isolated from research on what is necessarily a large and complex question (Keating, 1980a). For purposes of development, what we need instead is a better understanding of the acquisition of well-integrated operational and content knowledge structures (Keating & MacLean, 1988).

Evidence from a series of studies by Kuhn and her colleagues (Kuhn et al., 1988) suggests, in fact, that such progress is not merely one of acquisition. Rather, individuals -- both adolescents and adults -- have attachments to their causal theories, and they resist evaluating evidence that is contrary to those theories. Simply learning some "rules of thinking" is unlikely to overcome this resistance. Thus, the potential risks of independently learning reasoning skills from content knowledge are further highlighted.

On the other hand, it is important to bear in mind that, regardless of the longer-term transferability of skills promoted in the myriad "teaching of thinking" programs, there is no evidence that contradicts the assumption that pre- and early adolescents can in fact acquire the specifically targeted skills. Given the weaknesses of the evaluation literature as a whole, this null finding is not particularly convincing. Nonetheless, claims that certain kinds of thinking are inaccessible do not receive support from this literature on the training approach to critical thinking skills.

For those who might wish to push the computer analogy to the limits, the intrusion of an executive monitor into the human information processing system is a serious one. The system does not operate; instead, someone operates the system. There are two important -- and unavoidable -- features of cognitive activity subsumed under this heading. The first is most broadly termed "metacognition." Although the ability or inclination to

monitor one's own cognitive activity (for consistency, for gaps in information which need to be remedied, for checking the accuracy of some procedural application, and so on) can easily be categorized as part of critical thinking, it is less clear that efforts to independently enhance this will be very successful. At the simplest level, such efforts may reduce to mere exhortations to students to "THINK!" More elaborate attempts to enhance metacognitive activity have encountered some of the same difficulties as (and sometimes overlap conceptually with) programs for direct instruction of thinking processes. Specifically, individuals often have difficulty transferring such skills to any content outside of that in which it was first learned (Brown, Bransford, Ferrara, & Campione, 1983; Cavanaugh & Perlmutter, 1982). One might even imagine the possibility that a focus on such activities could be counterproductive early in the learning process, by drawing conscious attention to activities which might better be left alone in order to proceed toward automaticity. In this sense, metacognition may be a luxurious epiphenomenon of the already accomplished expert: Once a difficult skill or domain has been mastered, attention can be given over to whether or not the system is operating smoothly.

A second kind of monitoring is much more problematic for cognitive developmental theories of any kind. If we conceive of thinking as purposeful and goal-directed (Vygotsky, 1978), then we are compelled to recognize that the goals of the test-taker may not be those of the test-giver, and the goals of the student may not be the same as those of the teacher. This intrusion of the individual's own goals, motivations, and commitments opens the floodgates on our typically "closed system" models of thinking, learning, and teaching. It may yet prove the case that many of the constraints on higher order thinking are not cognitive in any important way, but derive instead from questions of motivation and goals (Dweck, 1986).

In summary, the emerging cognitive science models have focused more on the acquisition of expertise as a domain-by-domain process, and have begun to accumulate some substantial supportive evidence. This again raises problems for a belief in broad, fundamental developmental constraints. From a cognitive processing perspective, such limitations have not emerged as key potential factors; instead, the level of prior domain knowledge seems to be of far greater importance.

CONCLUSIONS, EMERGING THEMES, AND IMPLICATIONS

From this brief review of research on adolescent cognitive development, I contend that there is no persuasive evidence of fundamental constraints on the ability of adolescents to engage in critical thinking. Although such claims, from a variety of theoretical perspectives, have been considered in this review, the empirical findings either contradict them, or at least fail to support them.

In reviewing this work, several issues emerge as central themes for the analysis of possible constraints on critical thinking among adolescents. First, and especially relevant

to empirical research on these questions, is the degree to which such thinking can more usefully be considered as a general ability, or instead as necessarily tied to specific domains of content knowledge. Second, there is a question, perhaps even more fundamental, as to whether the metaphor of "skill" is in fact the most appropriate one (Schrag, 1988). Acceptance of the skill metaphor has a number of important implications both for psychological models of thinking and for educational practice addressed to its enhancement. Certainly, a dispositional or intentionality hypothesis is equally legitimate in terms of current evidence. Third is the issue of whether it is helpful to regard the various aspects of thinking as relatively more independent (and perhaps hierarchical) or more interdependent, even unitary. The educational implications of this are substantial: Are they developmentally more appropriate, or might they in some cases interfere with knowledge acquisition?

These recurring themes -- generalizability of thinking, thinking as a skill versus an orientation, and the independence versus interdependence of aspects of higher order thinking -- are obviously closely related to each other. It would be naive to expect any final resolution of such long-standing questions. It is to be hoped, however, that critical analysis of the constraints on critical thinking might illuminate them.

The research synthesis does, however, support the belief that fundamental developmental limitations are not a significant source of performance limitations for adolescents. It seems evident from an evaluation of current research that the source of the limitations is more likely to be found in our educational practices. Some plausible candidates arise from interpretations of the current developmental work in thinking and reasoning.

First, it is quite clear that test-driven demands for accountability affect both teachers and students dramatically. As Frederiksen (1984) has pointed out, this "test bias" has come to affect what is considered legitimate within school curricula. If key aspects of critical thinking are devalued by not being assessed for any reason that "counts," then teachers are less likely to demand it of students. Students, in turn, learn what is and is not important in the eyes of the school and the community. The elaborate credentialing system of education is designed partly as a social force to motivate students to acquire necessary skills. By failing to denote critical thinking as "necessary" -- since we don't test for it, and it is only the test scores that are used for purposes of accountability -- such activity disappears from school.

Second, there are many reasons to believe that the development of higher order reasoning rests squarely on the availability of ample amounts of relevant discourse (Glaser, 1984; Keating & MacLean, 1988; Newmann, 1985; Vygotsky, 1978). "Interactive inquiry methods are powerful tools for teaching thinking in context of subject matter (Glaser, 1984, p. 101)." But adequate opportunity for real discourse is hard to come by in middle or junior high schools (e.g., Goodlad, 1983). There are many other demands on teachers, both for non-academic supervision, and for coverage of the academic material likely to be

needed by students on tests. To be successful, such discourse or interactive inquiry must be finely tuned to the actual developmental level of the students. It "requires that a teacher be continually vigilant and keep in mind the particulars of each student's thinking (Glaser, 1984, p. 101)." With even average class sizes, this is a daunting task, especially when the developmental levels within any given classroom may vary quite markedly. If, as seems likely, different approaches are called for at different phases of acquisition, the complexity increases geometrically. Organizational rearrangements which would dramatically reduce class size, at least for some reasonable proportion of the school day, could be expected on the basis of current research to accomplish a great deal for the enhancement of higher order thinking (Bennett, 1987).

When such discourse focuses on topics such as social studies or history, additional problems are encountered (Newmann, 1985). For a truly open, critical discourse, the recognition that knowledge is "problematic and tentative" (Newmann, 1985, p. 10) is essential. This viewpoint, however, runs counter to the socially appointed role as an authority that is imposed on teachers (Shor, 1980).

Thus, a host of factors conspire to limit discourse, and discourse seems essential to the development of critical thinking and reasoning. This presents an important challenge to researchers and educators. One route is to study teachers who are able to create an effective classroom climate for discourse, despite the constraints. To the extent that those skills might be acquired by others, changes within the present framework might be possible. A second route is to examine more closely the organizational and systemic factors which reinforce the current framework, in order to discover whether change is possible at that level. The accelerating level of dissatisfaction now being articulated may provide a rare historical opportunity to propose and enact such changes.

Finally, it is important to note that schools do not present the sole opportunities nor the sole barriers to critical thinking. Aspects of the larger culture conspire as well to instantiate and reinforce a non-critical perspective in all of us (cf. Shor, 1980, Chapter 2). Adolescents are clearly not immune from these influences. Thus, even major reform in the schools cannot be expected to carry the full weight of generating or preserving the habit of critical thinking.

Note

1. The reader should be aware that the centrality of the discontinuity claim for Piaget's theory is a point of dispute. One exchange on this topic can be found in Byrnes (in press) and Keating (in press a). One point of agreement, however, is that many applications of Piaget's model to education do not reflect either his core theory or the way in which Piaget would have approached the question. The focus of this review is on the prevailing use in education of the belief, not on a theoretical critique (but see Keating, in press b for such a critique).

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